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Elastic Instability and Pattern Formation in Confined Soft Elastomeric Films

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When a rigid flat object or a flexible plate is removed from a thin soft film, instability patterns appear at the interface in the form of bubbles or fingers. The wavelengths of these instabilities are independent of all material and geometrical properties of the system except the thickness of the film. These observations contrast the classical Saffman-Taylor type instability in which the instability pattern depends on the viscous and surface tension forces in addition to the thickness of the liquid film. In the case of elastic instability of the kind described here, the wavelength depends on the material properties of the films only when soft films of different elastic properties are separated from each other. In the later case, a co-operative instability mode develops, which is a non-linear function of the thicknesses and the elastic moduli of both the films. In contrast to the wavelengths of these instabilities, their amplitudes are strong functions of several material and geometric properties of the system. These problems can be analyzed using regular perturbation technique to obtain the excess deformations of the film over and above the base quantities. Furthermore, by estimating the excess energy of the system, it can be shown that instability develops when the films are critically confined. This point can be illustrated by pre-stretching the film or simply by adjusting the contact width between the film and the plate. The instabilities that develop at the interface are critical to understanding adhesion and friction of soft thin films as they act like nucleated interfacial cracks. We performed a simple experiment, in which a flat rigid glass prism is sheared off a soft elastomeric film. At a given tangential force, the prism starts to slide on the elastomeric film accompanied with the formation of bubbles at the interface due to elastic instability. These bubbles, the lateral dimensions of which are comparable to the thickness of the film, move across the interface with speeds 1000 times faster than the overall sliding speed of the prism. The process continues till the critical condition for fracture is reached. These studies may shed some light on the fast dynamics of shear crack propagation in other systems.